Serious Complications Related to Obstetric Anesthesia

The Serious Complication Repository Project of the Society for Obstetric Anesthesia and Perinatology

Robert D'Angelo, M.D., Richard M. Smiley, M.D., Ph.D., Edward T. Riley, M.D., Scott Segal, M.D., M.H.C.M.

CME

This article has been selected for the ANESTHESIOLOGY CME Program. Learning objectives and disclosure and ordering information can be found in the CME section at the front of this issue.

ABSTRACT

Background: Because of the lack of large obstetric anesthesia databases, the incidences of serious complications related to obstetric anesthesia remain unknown. The Society for Obstetric Anesthesia and Perinatology developed the Serious Complication Repository Project to establish the incidence of serious complications related to obstetric anesthesia and to identify risk factors associated with each.

Methods: Serious complications were defined by the Society for Obstetric Anesthesia and Perinatology Research Committee which also coordinated the study. Thirty institutions participated in the approximately 5-yr study period. Data were collected as part of institutional quality assurance and sent to the central project coordinator quarterly.

Results: Data were captured on more than 257,000 anesthetics, including 5,000 general anesthetics for cesarean delivery. There were 157 total serious complications reported, 85 of which were anesthesia related. High neuraxial block, respiratory arrest in labor and delivery, and unrecognized spinal catheter were the most frequent complications encountered. A serious complication occurs in approximately 1:3,000 (1:2,443 to 1:3,782) obstetric anesthetics.

Conclusions: The Serious Complication Repository Project establishes the incidence of serious complications in obstetric anesthesia. Because serious complications related to obstetric anesthesia are rare, there were too few complications in each category to identify risk factors associated with each. However, because many of these complications can lead to catastrophic outcomes, it is recommended that the anesthesia provider remains vigilant and be prepared to rapidly diagnose and treat any complication. **(ANESTHESIOLOGY 2014; 120:1505-12)**

THE incidences of serious complications related to obstetric anesthesia remain largely unknown, primarily because of the lack of large obstetric anesthesia databases. The incidences of complications reported in the literature are highly variable as they typically represent estimates from case reports, case series, or limited institutional cohorts. For example, the incidence of a "high spinal" after neuraxial local anesthetic administration ranges between 1:2,971[1] and 1:16,200[2] anesthetics and for epidural abscess from 1:1,930[3] to 1:205,000.[4] The lack of reliable information and clear, agreed-upon definitions of complications makes it difficult to conduct an appropriate informed consent discussion regarding the risks of obstetric anesthesia.

What We Already Know about This Topic

- The incidences of serious complications related to obstetric anesthesia are unknown

What This Article Tells Us That Is New

- The Serious Complication Repository Project of the Society for Obstetric Anesthesia and Perinatology captured data on approximately 257,000 parturients administered neuraxial or general anesthesia at 30 institutions between 2004 and 2009
- Serious anesthesia-related complications were reported for 85 (1 of 3,000) patients
- The most common serious complications were high neuraxial block, respiratory arrest in labor suite, and unrecognized spinal catheter

This article is featured in "This Month in Anesthesiology," page 1A. Corresponding article on page 1311. This work was presented, in part, at the 2010 Society for Obstetric Anesthesia and Perinatology Annual Meeting, San Antonio, Texas, May 12–16, 2010, and 2013 Sol Shnider Obstetric Anesthesia Meeting, San Francisco, California, March 14–17, 2013.

Submitted for publication October 8, 2013. Accepted for publication February 25, 2014. From the Department of Anesthesiology, Wake Forest University School of Medicine, Winston-Salem, North Carolina (R.D.); Department of Anesthesiology, Columbia University Medical Center, New York, New York (R.M.S.); Department of Anesthesiology, Stanford University School of Medicine, Stanford, California (E.T.R.); and Department of Anesthesiology, Tufts University School of Medicine, Boston, Massachusetts (S.S.).

 Anesthesiology 2014; 120:1505-12

A large comprehensive database that systematically captures delivery statistics and tracks complications is necessary to produce accurate estimations of the incidence of complications. A database and reporting system that also captures information on the clinical events and outcomes associated with each serious complication has the potential to improve patient safety if the risk factors associated with each complication are identified and reported in the form of practice advisories or guideline recommendations. The Society for Obstetric Anesthesia and Perinatology (SOAP) created the **S**erious **Co**mplication **Re**pository (SCORE) Project primarily to establish the incidence of serious complications related to obstetric anesthesia and secondarily to identify risk factors associated with each complication.

Materials and Methods

Serious obstetric anesthesia complications to be tracked in the SCORE Project were defined by the SOAP Research Committee as: maternal death (whether or not caused by anesthesia), cardiac arrest (whether or not caused by anesthesia), epidural abscess or meningitis, epidural hematoma, serious neurologic injury (any central nervous system or peripheral injury requiring neuroimaging or a consultation), aspiration (documented radiologic findings consistent with clinical event), failed intubation, high neuraxial block (necessitating intubation or conversion to general anesthesia), anaphylaxis, and respiratory arrest in labor and delivery. The Section on Obstetric Anesthesia at the Wake Forest University School of Medicine was selected as the primary sponsor institution and central repository for data collection. After legal and Institutional Review Board approval, which included waiver of informed consent, institutional participation criteria and study goals were distributed to the entire SOAP membership *via* e-mail to recruit centers for reporting. Participation in the SCORE Project was limited to institutions that had established quality assurance programs that could reliably capture information on delivery statistics, anesthesia usage, serious complications, and details specific to each complication.

Thirty institutions participated in the study (see Acknowledgements); however, enrollment was open and institutions came on-line at various times throughout the study duration if and when criteria for enrollment and reporting were met. Institutional Review Board approval from each institution was obtained per local Institutional Review Board requirements. Data were collected through each participating institution's quality assurance program and faxed to the central repository at Wake Forest University quarterly using a standardized clinical data reporting form and complication description forms (CDFs) specific for each complication. The clinical data reporting form included information on the dates covered in the report, number and mode of deliveries during the time period, anesthesia technique usage, failed regional anesthesia that required an alternate technique for cesarean delivery, patients diagnosed with a postdural puncture headache, epidural blood patches (EBPs), repeat EBP, and the number of serious complications as defined by SCORE. The number of forms faxed each quarter was variable: the clinical data reporting form was the only form faxed when no serious complications occurred during the reporting quarter. Otherwise, one CDF was faxed for each serious complication reported during the quarter and included information specific to each complication. For example, a high neuraxial block CDF included information on where the event took place, timing of symptom onset in relation to the neuraxial anesthetic administration, patient risk factors, anesthetic type and administration techniques, drugs administered, and outcome. Only deidentified patient information was included in the faxed forms.

The data were collated, pooled, and entered into the database quarterly from October 1, 2004 to June 30, 2009 by one of the investigators. Each CDF was independently reviewed by the four investigators and every complication was assigned one of three rankings: anesthesia related, possibly anesthesia related, or not anesthesia related. A majority three of four or four of four agreement was necessary for classification. Complications that did not have majority agreement were reviewed by a fifth member of the SOAP Research Committee.

Statistical Analysis

Data intervals were analyzed using SAS 9.2 (SAS Inc., Cary, NC). Delivery, anesthesia technique, EBP, and high spinal statistics are reported as actual counts and percentages, cardiac arrests and maternal mortality statistics are reported as actual counts, and complications and postdural puncture headache are reported as actual counts as well as incidence with exact 95% CIs. To compare proportions of complications and deliveries across centers, data from each institution were converted to complications per 10,000 deliveries and the mean ± SD were estimated. To compare variations in proportions across years, the number of deliveries and complications for each year were converted to complications per 10,000 deliveries and the exact 95% CIs were estimated and compared.

Results

Thirty institutions provided data on more than 307,000 deliveries and 157 complications. The number of deliveries per year at participating institutions ranged from 1,000 to 10,000 with a mean ± SD of 4,247 ± 2,568. Deliveries, complications, complication per delivery ratios, complications per 10,000 deliveries with exact 95% CI, and the number of centers that participated in the SCORE Project each year are reported in table 1. There was no difference in total deliveries, complications, and the number of participating centers reported each year of the study. No institution contributed more than 11.6% of the total deliveries or 15.9% of the complications. Twenty-three (77%) participating institutions reported complications; however, the seven institutions that reported no complications also contributed relatively few deliveries to the database: 15,101 (range, 237 to 3,661) or 4.9% of total deliveries. When converted to

Table 1. Delivery Totals, Complications, Complication Ratios, and Number of Participating Centers per Year

Year	Deliveries	Complications	Complication/Deliveries	Complications per 10,000 Deliveries (Exact 95% CI)*	No. of Centers†
1	54,021	31	1:1,743	5.7 (4.1–8.1)	21
2	61,537	40	1:1,538	6.5 (4.8–8.9)	20
3	58,628	29	1:2,022	5.0 (3.5–7.1)	19
4	67,769	32	1:2,118	4.7 (3.4–6.7)	19
5‡	65,532	25	1:2,621	3.8 (2.6–5.6)	17
	307,495	157	1:1,959	5.1 (4.4–6.0)	30

* No significant difference among groups when comparing complications per 10,000 deliveries ratios during each year of the study. † Total number of institutions that participated in the Serious Complication Repository (SCORE) Project was 30; however, only 10 institutions participated in the entire 5 yr. ‡ Data collected for only three quarters during year 5 (the study was stopped after 19 quarters).

Table 2. Delivery Statistics and Anesthetic Technique Usage

Variable	Totals	Percentages
Total deliveries	307,495	
Total anesthetics	256,795	83.5% of total deliveries
Vaginal deliveries	211,368	68.7% of total deliveries
Neuraxial anesthetics for vaginal delivery	160,668	76.0% of vaginal deliveries
Epidural technique	100,828	62.8%
Combined spinal epidural technique	59,027	36.7%
Spinal technique	359	0.2%
Continuous spinal catheter technique	454	0.3%
Cesarean deliveries	96,127	31.3% of total deliveries
Neuraxial anesthetics for cesarean delivery	90,795	94.4% of neuraxial anesthetics
Spinal technique	34,323	37.8%
Epidural technique	30,632	33.7%
Combined spinal epidural technique	25,607	28.2%
Continuous spinal catheter technique	233	0.3%
General anesthesia	5,332	5.6% of cesarean deliveries
No. of failed neuraxial anesthetics for cesarean delivery	1,522	1.7%

Table 3. Postdural Puncture Headache and Epidural Blood Patch Statistics

Variable	Totals	Percentage	Incidence (95% CI)
Known dural punctures*	115,070		
Total neuraxial anesthetics†	237,437		
No. of postdural puncture headaches	1,647	0.7% of all neuraxial anesthetics	1:144‡ (1:137, 1:151)
No. of epidural blood patches	917	55.7% of postdural puncture headaches	
Repeat epidural blood patches	98	10.7% of epidural blood patches	

* Includes spinal, combined spinal epidural, and continuous spinal anesthetics. The incidence of "wet tap" or dural puncture with the epidural needle was not tracked in the database. † The total neuraxial anesthetics listed above are from institutions that provided statistics on postdural puncture headache and epidural blood patch. Not all institutions tracked these variables as part of quality assurance. ‡ The risk of postdural puncture headache from all neuraxial anesthetic techniques, including epidural anesthesia.

complications per 10,000 deliveries, the variation across the 30 participating institutions was as follows: min = 0, max = 11.5, mean ± SD = 4.74 ± 3.78.

Data were collected on approximately 257,000 patients in whom neuraxial or general anesthesia was administered for delivery. Delivery statistics and anesthesia technique usage for vaginal and cesarean deliveries are reported in table 2. Neuraxial anesthesia was used in 76% of vaginal deliveries and 94.4% of cesarean deliveries. The incidence of failed neuraxial anesthesia that required an alternate technique for cesarean delivery was 1.7%.

Postdural puncture headache and EBP statistics are reported in table 3. The percentage of patients who developed a postdural puncture headache after receiving a neuraxial anesthetic was 0.7%. Fifty-five and seven-tenth percentage of patients with a postdural puncture headache received an EBP and 10.7% of these patients required a second EBP. The SCORE Project was not designed to track the incidence of inadvertent dural punctures with epidural needles.

The number, incidence, and exact 95% CIs for serious complications are listed in table 4. There were 157 total complications, 85 of which were anesthesia related. During scoring of the complications, there was complete agreement by the reviewers (four of four) with 127 (80.9%) complications, three of four agreement with 26 (16.6%) complications, and four (2.5%) of the complications were reviewed by a fifth reviewer due to a 2/2 tie. Eighty-five complications were categorized as anesthesia related, 9 as possibly anesthesia related, and 63 as nonanesthesia related. The nine complications listed as possibly anesthesia related were not included as anesthesia-related complications in table 4 and

Table 4. Incidence of Serious Complications*

Serious Complication	Totals	Incidence	95% CI	Anesthesia Related	Incidence	95% CI
Maternal death	30	1:10,250	1:7,180, 1:15,192	0		
Cardiac arrest	43†	1:7,151	1:5,319, 1:9,615	2	1:128,398	1:35,544, 1:1,060,218
Myocardial infarction	2	1:153,748	1:42,562, 1:1,269,541	2	1:128,398	1:35,544, 1:1,060,218
Epidural abscess/meningitis	4			4	1:62,866	1:25,074, 1:235,620
Epidural hematoma	1			1	1:251,463	1:46,090, 1:10,142,861
Serious neurologic injury	27	1:11,389	1:7,828, 1:17,281	7	1:35,923	1:17,805, 1:91,244
Aspiration	0			0		
Failed intubation	10			10	1:533	1:290, 1:971
High neuraxial block	58			58‡	1:4,336	1:3,356, 1:5,587
Anaphylaxis	5§	1:61,499	1:26,353, 1:189,403	0		
Respiratory arrest in labor suite	25	1:8,455	1:5,714, 1:12,500	16	1:10,042	1:6,172, 1:16,131
Unrecognized spinal catheter	14			14	1:15,435	1:9,176, 1:25,634
Total	157‖	1:1,959	1:1,675, 1:2,294	85#	1:3,021	1:2,443, 1:3,782

* The incidence and 95% CI are listed only once when solely related to anesthesia. † Fourteen cardiac arrests did not result in maternal death. ‡ Also includes high blocks on labor and delivery that resulted in respiratory arrests from local anesthetic administration. § The medications associated with anaphylaxis were administered by anesthesia personnel but were not anesthesia medications. ‖ There were 157 total serious complications; however, some complications are listed in more than one category. # There were 85 anesthesia-related serious complications; however, some complications are listed in more than one category.

Table 5. Causes of Maternal Death

Causes*	Number
Hemorrhage	10
Preexisting cardiac disease	5
Hypertension	3
Amniotic fluid embolism	3
Pulmonary embolism	2
Anaphylaxis	2
Cocaine	2
Infection/sepsis	2
Unreported cause	1
Total	30

* Each patient is listed in only one category although many can easily be listed in multiple categories; for example, depending on the clinical presentation, an amniotic fluid embolism can also be categorized into cardiac arrest and hemorrhage categories.

were as follows: five neurologic complications, one cardiac arrest, and three maternal deaths. The most frequent serious complication encountered secondary to neuraxial anesthesia was high neuraxial block, which occurred in 1 of every 4,336 anesthetics. No cases of aspiration of gastric contents related to general anesthesia during cesarean delivery were reported; however, 1 of every 533 general anesthetics resulted in failed intubation. There were two cardiac arrests that were related to anesthesia. One involved the intravenous administration of local anesthetic during a transversus abdominis plane block, which was successfully treated with lipid emulsion. The other arrest was related to hypoxemia from a high neuraxial block in a morbidly obese patient. Both patients survived. The drugs associated with anaphylaxis were: ampicillin, cefazolin, latex, and metoclopramide. In a fifth case, the identity of the drug that resulted in anaphylaxis and maternal death was never identified.

The causes of maternal death are listed in table 5. Hemorrhage and preexisting cardiac disease were the leading causes of death. Causes of hemorrhage include: two cases of postpartum disseminated intravascular coagulation, two cases of disseminated intravascular coagulation secondary to infection, two cases of amniotic fluid embolism, two cases of ruptured thoracic aneurism, and single cases of complete placenta previa, placenta accreta, uterine arteriovenous malformation, and preexisting thrombocytopenia purpura. All five patients with preexisting cardiac disease had cardiomyopathy: two associated with systemic lupus erythematosus, two with peripartum cardiomyopathy, and the last associated with chemotherapy previously administered to treat breast cancer. Cesarean was the mode of delivery for 85% of patients who experienced maternal death.

The causes of cardiac arrest and the number of patients who survived resuscitation are listed in table 6. Hemorrhage, preexisting cardiac disease, and amniotic fluid embolism were the leading causes of cardiac arrest. Fourteen patients (32.6%) with cardiac arrest survived, 12 of whom made full recoveries and two who experienced permanent neurologic impairment secondary to anoxic encephalopathy. Cesarean was the mode of delivery for 88% of patients who experienced cardiac arrest.

The characteristics associated with high neuraxial anesthetics are listed in table 7. A majority of patients who developed a high neuraxial block from spinal and epidural anesthesia had known risk factors, the most frequent of which were obesity and the administration of spinal anesthetic after a failed epidural anesthetic. Ninety-three percent of unrecognized spinal catheters that resulted in a high neuraxial block occurred in the labor suite as opposed to the operating room, at a rate of 1 in every 12,297 labor epidurals (exact 95% CI, 1:7,194 to 1:20,842).

Table 6. Causes of Cardiac Arrest

Causes*	Number	Survived Resuscitation
Hemorrhage	12	3
Preexisting cardiac disease	7	2
Amniotic fluid embolism	7	3
Anaphylaxis	3	1
Pulmonary embolism	3	0
Hypoxia	2	2
Cocaine	2	0
Intracranial hemorrhage	2	0
Infection/sepsis	2	0
Local anesthetic toxicity	1	1
Hyperkalemia	1	1
Air embolism	1	1
Total	43	14 (32.6%)

* Each patient is listed in only one category although many can easily be listed into multiple categories; for example, depending on the clinical presentation, an amniotic fluid embolism can also be categorized into hemorrhage, anaphylaxis, and infection categories.

Table 7. Characteristics Associated with High Neuraxial Anesthetics

Variable	Number
Total high neuraxial anesthetics	58
Associated technique	
Spinal	23 (40%)
Epidural	21 (36%)
Unrecognized spinal catheter	14 (24%)
Occurred in labor suite	13
During cesarean delivery	1
Risk factors	38/44 (86%)
Obesity	18
Spinal technique after failed epidural anesthesia	12
Height <60 inches	4
Epidural after wet tap	3
Spinal deformity	1

Discussion

The primary objective of the SCORE Project, to establish the incidences of serious complications related to obstetric anesthesia, was achieved with a reasonable degree of certainty. In contrast, there were too few serious complications in each category captured during the approximately 5-yr study period to identify associated risk factors. Because of the rarity of these events, the study was underpowered to capture significant numbers of serious complications. Therefore, although it is not possible to create evidence-based practice advisories from the SCORE Project findings, the results can be used to guide discussions involving informed consent and to make practical recommendations. For example, the most common serious complication reported in the study was high neuraxial block necessitating intubation, which occurred in 1 of every 4,336 regional anesthetics (table 4). This finding further supports guidelines recommending the ready availability of emergency airway equipment in obstetric settings.* In addition, spinal anesthesia after a failed epidural anesthetic in patients with an anticipated difficult airway should be considered with caution, especially considering that more than 25% of high neuraxial blocks occurred in this relatively unusual clinical context, implying that the incidence in that context may be relatively high.

Despite the limited information regarding risk factors, the SCORE Project represents the most comprehensive database to date assessing complications in the subspecialty of obstetric anesthesia. For example, in contrast to the extreme ranges for epidural abscess reported in the literature ranging from 1:1,930[3] to 1:205,000,[4] the incidence of epidural abscess in the SCORE Project was 1:62,866 and likely represents the most realistic estimate available.

It is reassuring that serious complications related to anesthesia occur so rarely in the obstetric population. A number of changes in obstetric anesthesia practice in recent decades have improved patient safety; arguably, the two most important are the nearly universal use of dilute local anesthetic solutions during labor and the increased use of neuraxial anesthesia during labor and for cesarean delivery.[5] There was only one instance of cardiac arrest associated with intravascular injection of local anesthetic (and that was not a neuraxial anesthetic) and no instances of aspiration of gastric contents, historically one of the feared serious complications in obstetric anesthesia. The lack of a serious aspiration event in more than 5,000 general anesthetics may suggest that this complication is not as common as previously noted or suspected. This is consistent with the report on maternal mortality in Michigan, where none of the deaths was from aspiration.[6] There was a fairly high rate of failed intubation, in the range frequently reported,[7,8] but no hypoxemic arrests resulted from those cases. The good outcomes associated with failed intubations may be because of improved airway management techniques now readily available.[9] This is consistent with the most recent study reported by Hawkins *et al.*[10] on maternal mortality suggesting similar rates from both general and regional anesthesia and the Closed Claims analysis on obstetric anesthesia that found a decrease in claims related to difficult intubation after 1999.[11] Because the risk of failed intubation remains high and modern airway equipment is so effective, it is recommended that every practice should ensure the ready availability of equipment to manage the difficult airway in the labor suite and obstetric operating rooms.[11]*

There were 13 high neuraxial blocks reported in laboring patients in the current study of more than 160,000 epidural and combined spinal epidural anesthetics. Although information on whether and how epidural catheters were tested after insertion in the current study was not obtained, it has

* Guidelines for neuraxial anesthesia in obstetrics (2010). Available at: http://www.asahq.org/For-Members/Standards-Guidelines-and-Statements.aspx. Accessed January 21, 2014.

been suggested that routine testing of epidural catheters for inadvertent intrathecal or intravenous placement is unnecessary for two reasons: aspiration of an epidural catheter for cerebrospinal fluid or blood after insertion has a high sensitivity and specificity, and the nearly universal use of dilute local anesthetic solutions during labor.[12] In addition, testing a catheter for misplacement does not guarantee proper placement as the majority of epidural anesthetics associated with high neuraxial block and maternal death in the 2009 Closed Claims report occurred after an uneventful test dose.[11] Because the loss of an airway in the uncontrolled labor and delivery setting can be catastrophic, it is recommended that the anesthesia provider remain ever vigilant for a misplaced epidural catheter.

Additional limitations of the SCORE Project include retrospective data collection, the relatively small number of participating institutions, a high percentage of academic institutions enrolled in the study, and the lack of funding for data monitors. Data collection and CDFs were standardized to facilitate consistent data entry and returned quarterly. In addition, the primary investigator at each institution was a SOAP member who voluntarily agreed to comply with the study protocol. Although the data were retrospectively collected, participation was limited to institutions with active quality assurance programs, so most of the complications were recorded and investigated or classified near to the time they occurred by personnel familiar with the clinical environment and context. It is likely these measures increased the likelihood that reliable information was returned to the central repository. There is no reason to doubt that participating institutions acted in good faith to supply reliable information quarterly. Nevertheless, without the use of study monitors and site visits, it cannot be guaranteed that institutions captured or reported every serious complication that occurred during the approximately 5-yr study period. Although data monitor use is an essential validation tool in large sustained databases,† there was no funding for data monitors or site visits.

The relatively high percentage of academic institutions participating in the study may have increased the number of total complications reported because academic institutions typically care for a larger percentage of high-risk patients, such as those with severe preeclampsia, morbid obesity, history of hemorrhage or with preexisting severe cardiac, and neurologic comorbidity, who in turn may be more likely to experience serious complications. Care is also predominantly delivered in these institutions by residents supervised in various ways by attending anesthesiologists, which could affect complication rates. Conversely, academic centers may be better staffed and equipped to care for patients with complicated pregnancies or anesthesia complications, which may in theory reduce the risk of developing a serious complication or of catastrophic outcomes. Despite this limitation, comparison of the SCORE Project results with other databases demonstrates strikingly similar findings. Examples include the incidence of cesarean delivery and maternal mortality. According to the U.S. Center for Vital Statistics, the incidence of cesarean delivery from 2004 to 2009 was 31.2% compared with 31.3% observed in the SCORE Project.[13–18] In-hospital maternal mortality in the United States during this period was 0.8:10,000 births[19] compared with 0.98:10,000 in the SCORE Project. These similarities are reassuring and suggest that the data captured in the SCORE Project were reasonably representative of the U.S. population and practice.

Participating institutions were asked to report cardiac arrests and maternal deaths whether or not anesthesia related, because regardless of the cause, many of these events occur on the labor suite and anesthesia providers are involved in the resuscitation of these patients. It is estimated that anesthesia providers were involved in 98% of the cases of cardiac arrest and maternal death reported in the SCORE Project. Fortunately, only two of the cardiac arrests and none of the maternal deaths were related to anesthesia (tables 5 and 6). Although sepsis was found to be the leading cause of maternal death in the latest triennial report,[20] obstetric hemorrhage remains a leading cause of maternal mortality and was the leading cause of maternal death in the SCORE Project. It may be that septic deaths often occur outside the labor and delivery suite and were not captured by the reporting system of SCORE Project. Institutions that care for obstetric patients should consider the implementation of massive transfusion protocols that have been shown to reduce blood use and complications in the trauma population[21] and may have a role in the obstetric population.[22,23]

Although the SCORE Project captured information on more than 300,000 deliveries, this represents only 1.5% of the more than 20,000,000 U.S. births during the same time period.[13–18] Even though serious complications related to obstetric anesthesia are rare, a large number of births theoretically translate into a large number of complications. Extrapolating SCORE Project findings to the 20 million births suggests that as many as 640 failed intubations, 260 epidural abscesses, 65 epidural hematomas, 3,790 high neuraxial blocks, and 680 unrecognized spinal catheters occurred in the United States during the approximately 5-yr study period.

Obtaining information on many more complications is a worthwhile patient safety goal. Next steps in this process should include the creation of a national obstetric anesthesia database and/or a serious complication registry. Since the completion of the SCORE Project, there have been initiatives to create both a national anesthesia database and subspecialty complication registries. The American Society of Anesthesiologists created the Anesthesia Quality Institute in 2009 which launched its database the National Anesthesia Clinical

† The Society of Thoracic Surgeons National Database. Available at: www.sts.org/national-database. Accessed January 21, 2014.

Outcomes Registry in 2010‡ and SOAP is currently working with Anesthesia Quality Institute to create an Obstetric Anesthesia Complication Registry as part of the Anesthesia Quality Institute Anesthesia Incident Reporting System.§

Acknowledgments

The authors thank the following project coordinators and institutions for their participation in the SCORE Project. Each coordinator obtained Institutional Review Board approval as appropriate, collected quality assurance information, and completed the necessary forms per protocol requirements. Without their efforts, the study would not have been possible: Curtis Baysinger, M.D., Vanderbilt University, Nashville, Tennessee; James Bates, M.D., University of Iowa, Iowa City, Iowa; Yaakov Beilin, M.D., Mount Sinai Hospital, New York, New York; John Collins, M.D., Lehigh Valley Hospital, Allentown, Pennsylvania; Anne Contendo, M.D., University of Arizona, Tuscon, Arizona; Robert D'Angelo, M.D., Wake Forest University, Winston-Salem, North Carolina; Libby Ellinas, M.D., Medical College of Wisconsin, Milwaukee, Wisconsin; Joy Hawkins, M.D., University of Colorado, Denver, Colorado; Dana Hershey, M.D., Carolinas Medical Center, Charlotte, North Carolina; Phil Hess, M.D., Beth Israel Deaconess Medical Center, Boston, Massachusetts; Joseph Hranac, M.D., St. Elizabeth Regional Medical Center, Lincoln, Nebraska; Kim Ku-Mie, M.D., Loyola University, Chicago, Illinois; Barbara Leighton, M.D., Washington University, Saint Louis, Missouri; Isaac Lowenwirt, M.D., New York Hospital Medical Center, New York, New York; Andy Malinow, M.D., University of Maryland, College Park, Maryland; Christy Morgan, M.D., St. John Mercy Medical Center, Saint Louis, Missouri; Luis Orosco, M.D., Women's Hospital of Texas, Houston, Texas; Kiki Palacios, M.D., Baylor College of Medicine, Houston, Texas; Lang Ha Pham, M.D., Presbyterian Hospital, Albuquerque, New Mexico; Michael Rochin, C.R.N.A., San Angelo Community Medical Center, San Angelo, Texas; Kenneth Rudman, M.D., Sparrow Hospital, Lansing, Michigan; Steve Schwalbe, M.D., Elmhurst Hospital Center, New York, New York; Grace Shih, M.D., University of Kansas, Lawrence, Kansas; Richard Smiley, M.D., Columbia University, New York, New York; Kathy Stack, M.D., Emory University, Atlanta, Georgia; Lawrence Tsen, M.D., Brigham and Women's Hospital, Boston, Massachusetts; Reyne Viergutz, M.D., Faith Regional Health Services, Norfolk, Nebraska; Scott Wheeler, M.D., University of Texas, Austin, Texas; Danny Wilkerson, M.D., University of Arkansas, Fayetteville, Arkansas; and Cynthia Wong, M.D., Northwestern University, Chicago, Illinois.

The Society for Obstetric Anesthesia and Perinatology (Milwaukee, Wisconsin) provided a $6,000 grant to support data entry.

Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to Dr. D'Angelo: Forsyth Medical Center, 3333 Silas Creek Parkway, Winston-Salem, North Carolina 27103. rdangelo@wakehealth.edu. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

References

1. Scott DB, Tunstall ME: Serious complications associated with epidural/spinal blockade in obstetrics: A two-year prospective study. Int J Obstet Anesth 1995; 4:133–9
2. Jenkins JG: Some immediate serious complications of obstetric epidural analgesia and anaesthesia: A prospective study of 145,550 epidurals. Int J Obstet Anesth 2005; 14: 37–42
3. Wang LP, Hauerberg J, Schmidt JF: Incidence of spinal epidural abscess after epidural analgesia: A national 1-year survey. Anesthesiology 1999; 91:1928–36
4. Moen V, Dahlgren N, Irestedt L: Severe neurological complications after central neuraxial blockades in Sweden 1990–1999. Anesthesiology 2004; 101:950–9
5. Bucklin BA, Hawkins JL, Anderson JR, Ullrich FA: Obstetric anesthesia workforce survey: Twenty-year update. Anesthesiology 2005; 103:645–53
6. Mhyre JM, Riesner MN, Polley LS, Naughton NN: A series of anesthesia-related maternal deaths in Michigan, 1985–2003. Anesthesiology 2007; 106:1096–104
7. Quinn AC, Milne D, Columb M, Gorton H, Knight M: Failed tracheal intubation in obstetric anaesthesia: 2 yr national case-control study in the UK. Br J Anaesth 2013; 110: 74–80
8. McDonnell NJ, Paech MJ, Clavisi OM, Scott KL; ANZCA Trials Group: Difficult and failed intubation in obstetric anaesthesia: An observational study of airway management and complications associated with general anaesthesia for caesarean section. Int J Obstet Anesth 2008; 17:292–7
9. Tsen LC, Pitner R, Camann WR: General anesthesia for cesarean section at a tertiary care hospital 1990–1995: Indications and implications. Int J Obstet Anesth 1998; 7:147–52
10. Hawkins JL, Chang J, Palmer SK, Gibbs CP, Callaghan WM: Anesthesia-related maternal mortality in the United States: 1979–2002. Obstet Gynecol 2011; 117:69–74
11. Davies JM, Posner KL, Lee LA, Cheney FW, Domino KB: Liability associated with obstetric anesthesia: A closed claims analysis. Anesthesiology 2009; 110:131–9
12. Norris MC, Fogel ST, Dalman H, Borrenpohl S, Hoppe W, Riley A: Labor epidural analgesia without an intravascular "test dose". Anesthesiology 1998; 88:1495–501
13. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Kirmeyer S: Births: Final data for 2004. Natl Vital Stat Rep 2006; 55:1–101
14. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Kirmeyer S, Munson ML: Births: Final data for 2005. Natl Vital Stat Rep 2007; 56:1–103
15. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Kirmeyer S, Mathews TJ: Births: Final data for 2006. Natl Vital Stat Rep 2009; 57:1–102
16. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Mathews TJ, Kirmeyer S, Osterman JK: Births: Final data for 2007. Natl Vital Stat Rep 2010; 58:1–85
17. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Mathews TJ, Osterman MJ: Births: Final data for 2008. Natl Vital Stat Rep 2010; 59:1, 3–71
18. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Kirmeyer S, Mathews TJ, Wilson EC: Births: Final data for 2009. Natl Vital Stat Rep 2011; 60:1–70
19. Callaghan WM, Creanga AA, Kuklina EV: Severe maternal morbidity among delivery and postpartum hospitalizations in the United States. Obstet Gynecol 2012; 120:1029–36
20. Cantwell R, Clutton-Brock T, Cooper G, Dawson A, DrifeJ, Garrod D, Harper A, Hulbert D, Lucas S, McClure J,

‡ The Anesthesia Quality Institute (AQI) and the National Anesthesia Clinical Outcomes Registry (NACOR). Available at: www.aqihq.org. Accessed January 21, 2014.

§ The Anesthesia Incident Reporting System (AIRS). Available at: www.aqihq.org/airs/airsIntro.aspx. Accessed January 21, 2014.

Millward-Sadler H, Neilson J, Nelson-Piercy C, Norman J, O'Herlihy C, Oates M, Shakespeare J, de Swiet M, Williamson C, Beale V, Knight M, Lennox C, Miller A, Parmar D, Rogers J, Springett A: Saving mother' lives: Reviewing maternal deaths to make motherhood safer: 2006–2008. The eighth report of the confidential enquiries into maternal deaths in the United Kingdom. BJOG 2011; 118(suppl 1):1–203

21. Nunez TC, Young PP, Holcomb JB, Cotton BA: Creation, implementation, and maturation of a massive transfusion protocol for the exsanguinating trauma patient. J Trauma 2010; 68:1498–505
22. Practice guidelines for perioperative blood transfusion and adjuvant therapies. An updated report by the American Society of Anesthesiologists task force on perioperative blood transfusion and adjuvant therapies. ANESTHESIOLOGY 2006; 105:198–208
23. Gutierrez MC, Goodnough LT, Druzin M, Butwick AJ: Postpartum hemorrhage treated with a massive transfusion protocol at a tertiary obstetric center: A retrospective study. Int J Obstet Anesth 2012; 21:230–5